FLEXIBLE SWITCHING DEVICES

CROSS REFERENCE TO RELATED APPLICATIONS

This is divisional application of U.S. Application Ser. No. 10/276,220, filed Nov. 14, 2002, now U.S. Pat. No. 7,145,432, which is a U.S. national phase application of PCT/GB01/02183, filed May 17, 2001, which claims priority to Great Britain Application No. 0011829.9, filed May 18, 2000, each incorporated herein by reference in its entirety.

TECHNICAL FIELD

This invention relates to electrical switching devices and more particularly to the architecture and construction of flexible switching devices and the use thereof in switching and proportional control of electric/electronic currents.

The working components of these devices can appear as and perform similarly to conventional textile materials and thus have applications as user-interfaces (including pressure sensors) particularly in the field of textile/wearable electronics. The devices are applicable as alternatives to 'hard' electronic user-interfaces. Generally the devices can be produced using commercial textile manufacturing processes but the invention is not limited to such processes.

In this specification:

'textile' includes any assemblage of fibres, including spun, monofil and multifilament, for example woven, non-woven, felted or tufted; and the fibres present may be natural, semi-synthetic, synthetic, blends thereof and metals and alloys;

'electronic' includes 'low' currents as in electronic circuits and 'high' currents as in circuits commonly referred as 'electric';

'user interface' includes any system in which a mechanical action is registered as a change in electrical resistance or conductance. The mechanical action may be for example conscious bodily action such as finger pressure or footfall, animal movement, pathological bodily movement, expansion or contraction due to bodily or inanimate temperature variation, displacement in civil engineering structures.

'mechanical deformation' includes pressure, stretching and bending and combinations of these.

SUMMARY OF THE INVENTION

The invention provides an electronic resistor user-interface comprising flexible conductive materials and a flexible variable resistive element capable of exhibiting a change in electrical resistance on mechanical deformation, characterised by textile-form electrodes, a textile-form variably resistive element and textile-form members connective to external circuitry.

It will be appreciated that the textile form of each component of the user-interface may be provided individually or by sharing with a neighbouring component.

The electrodes, providing a conductive pathway to and from either side of the variably resistive element, generally conductive fabrics (these may be knitted, woven or non-woven), yarns, fibres, coated fabrics or printed fabrics or printed fabrics, composed wholly or partly of conductive materials such as metals, metal oxides, or semi-conductive materials such as conductive polymers (polyaniline, polypyrrole and polythiophenes) or carbon. Materials used for coating or printing conductive layers onto fabrics may include inks or polymers containing metals, metal oxides or

semi-conductive materials such as conductive polymers or carbon. Preferred electrodes comprise stainless steel fibres, monofil and multifilament or stable conducting polymers, to provide durability under textile cleaning conditions.

The electrodes can be supported by non-conducting textile, preferably of area extending outside that of the electrodes, to support also connective members to be described.

Methods to produce the required electrical contact of the electrode with the variably resistive element include one or more of the following:

a) conductive yarns may be woven, knitted, embroidered in selected areas of the support so as to produce conductive pathways or isolated conductive regions or circuits;

b) conductive fabrics may be sewn or bonded onto the support;

c) conductive coatings or printing inks may be laid down onto the support by techniques such as spraying, screen printing, digital printing, direct coating, transfer coating, sputter coating, vapour phase deposition, powder coating and surface polymerisation.

Printing is preferred, if appropriate using techniques such as resist, to produce contact patterns at many levels of complexity and for repetition manufacture.

The extension of the support outside the electrode region is sufficient to accommodate the connective members to be described. It may be relatively small, to give a unit complete in itself and applicable to a user-apparatus such as a garment.

Alternatively it may be part of a user-apparatus, the electrodes and variably resistive element being assembled in situ. It may carry terminals at which the connective members pass the electric current to other conductors.

The variably resistive element, providing a controllable conductive pathway between the two electrodes, may take a number of forms, for example

a) a self-supporting layer;

b) a layer containing continuous or long-staple textile reinforcement;

c) a coating applied to the surface of textile eg. as fabrics, yarns or fibres. This coating preferably contains a particulate variably resistive material as described in PCT/GB99/00205, and may contain a polymer binder such as polyurethane, PVC, polyacrylonitrile, silicone, or other elastomer. Alternatively the variably resistive material may be for example a metal oxide, a conductive polymer (such as polyaniline, polypyrrole and polythiophenes) or carbon. This coating may be applied for example by commercial methods such as direct coating, transfer coating, printing, padding or spraying;

d) it may contain fibres that are inherently electrically conductive or are extruded to contain a variably resistive material as described in PCT/GB99/00205;

e) it may be incorporated into or coated onto one of the electrodes in order to simplify manufacturing processes or increase durability in certain cases.

The variable resistor generally comprises a polymer and a particulate electrically conductive material. That material may be present in one or more of the following states:

a) a constituent of the base structure of the element;

b) particles trapped in interstices and/or adhering to surfaces;

c) a surface phase formed by interaction of conductive particles (i or ii below) with the base structure of the element or a coating thereon.

Whichever state the conductive material of the variably resistive element is present in, it may be introduced:

i) 'naked', that is, without pre-coat but possibly carrying on its surface the residue of a surface phase in equi-